UNIVERSITY OF KWAZULU-NATAL

School of Electrical, Electronic & Computer Engineering

MAIN EXAMINATIONS: November 2016

Subject, Course and Code: **Analogue Electronics 2: ENEL3AE H2**

Duration: TWO hours | **Paper 1 of 1** | **Maximum marks: 70**

Examiner: Dr. V. M. Srivastava

Independent Moderator: Prof. T. J. O. Afullo

Instructions:

Answer the Question No. 1 **and** any other THREE Questions.

NO NOTES of any form are allowed into the examination.

Programmable calculators may be used, provided that no text or formulae are present in memory during the examination.

Ensure you give **full reasons** for all calculations and decisions in all questions.

Show all working in calculations and derivations.

Fully label all diagrams and graphs.

Question 1 [10 marks]

1.1 The complementary BJT follower shown in **Fig. 1.1(a)** has the approximate transfer characteristic shown in **Fig. 1.1(b)**. Observe that for $-0.7\text{ V} \leq V_I \leq +0.7\text{ V}$, the output is zero. This "dead band" leads to crossover distortion. Consider this follower to be driven by the output of a differential amplifier of gain *100* whose positive-input terminal is connected to the input signal source V_s and whose negative-input terminal is connected to the emitters of the follower.

Sketch the transfer characteristic V_o versus V_s of the resulting feedback amplifier. **(2)**

What are the limits of the dead band, and what are the gains outside the dead band? **(3+2)**

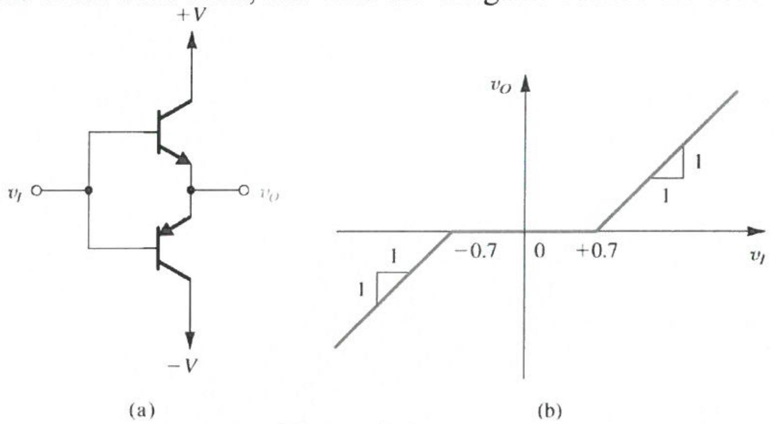

Figure 1.1

1.2 Briefly explain the need for non-linear amplitude control in most RC oscillator circuits. **(3)**

Question 2 [20 marks]

2.1 Consider the common-emitter amplifier of **Fig. 2.1**, under the following condition: $R_{sig} = 5\text{ k}\Omega$, $R_1 = 33\text{ k}\Omega$, $R_2 = 22\text{ k}\Omega$, $R_E = 3.9\text{ k}\Omega$. $R_C = 4.7\text{ K}\Omega$, $R_L = 5.6\text{ k}\Omega$, $V_{cc} = 5\text{ V}$. The DC emitter current can be shown to be $I_E = 0.3\text{ mA}$, at which $\beta = 120$, $r_o = 300\text{ k}\Omega$ and $r_s = 50\ \Omega$. If the transistor is specified to have $f_T = 700\text{ MHz}$ and $C_\mu = 1\text{ pF}$, find the upper 3-dB frequency f_H. **(10)**

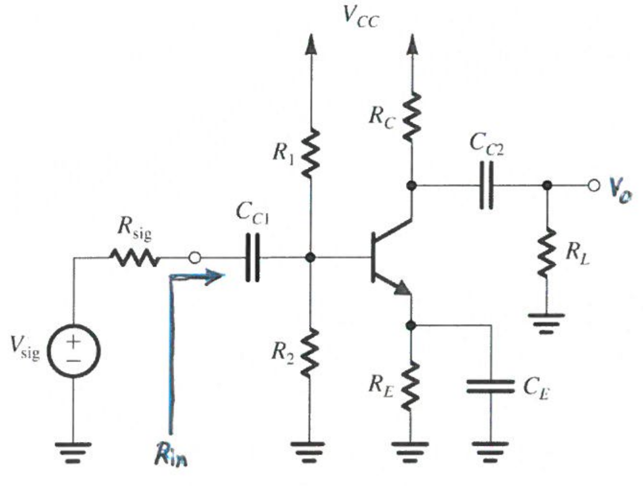

Figure 2.1

2.2 A design is required for a CS amplifier for which MOSFET is operated at g_m = 5 mA/V and has C_{gs} = 5 pF and C_{gd} = 1 pF. The amplifier is fed with a signal source having R_{sig} = 1 kΩ, and R_G is very large.

(i) What is the largest value of R'_L for which the upper 3-dB frequency is at least 10 MHz? **(4)**

(ii) What is the corresponding value of midband gain and gain-bandwidth product? **(2+2)**

(iii) If the specification on the upper 3-dB frequency can be relaxed by a factor of 3, that is, to (10/3) MHz, what can A_M and GB become? **(1+1)**

Question 3 [20 marks]

The circuit of a two-stage BJT amplifier with signal negative feedback via resistors R_1 and R_F is shown in **Fig. 3**. The differential input stage (Q_1, Q_2) and the output stage (Q_3) are dc biased by the current-steering circuit of Q_4, Q_5 & Q_6.

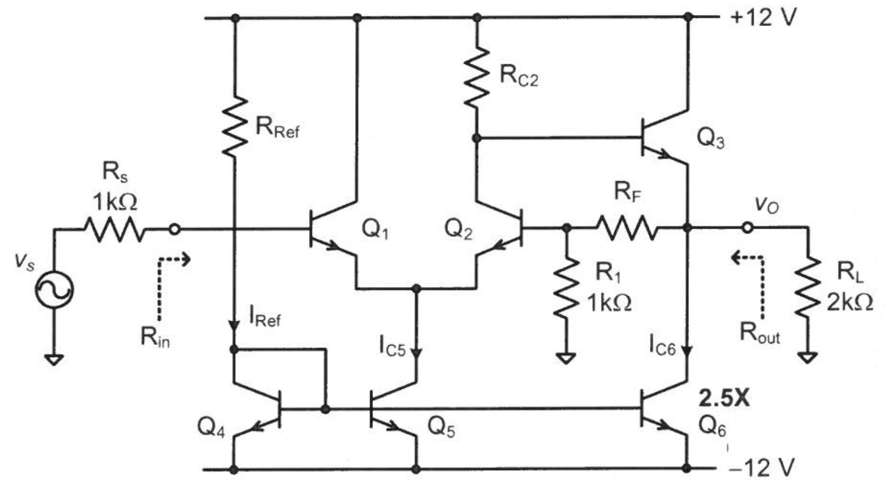

Figure 3

A. Assuming V_{BE} = 0.7 V and neglecting base currents, design values for R_{Ref} and R_{C2} so that $I_{Ref} = 2\,mA$ and $V_o = 0\,V$ dc. Assume signal source V_s has zero dc component and note the area of BJT Q_6 is 2.5 times the area of the other BJTs. Hence determine the dc bias conditions in the circuit. **(4)**

B. Identify the feedback topology of this amplifier clearly explaining **how** you made this identification, and state which transfer gain ("A_f") is stabilized by this feedback circuit. **(3)**

C. Draw a small-signal equivalent circuit of the "A" network without feedback but including the loading effects of the feedback network. Clearly explain **how** you determined the relevant loading effects. The design objective is to obtain a closed-loop voltage gain with feedback $A_{vf} \equiv v_o / v_s = 16$. Determine the value of R_F to meet this (ideally) assuming the open-loop gain is very large. **(3)**

D. Determine suitable small-signal models for the BJTs assuming $h_{fe} = 100$ and neglecting the Early effect. For this amplifier *with negative feedback*, determine the actual voltage gain $A_{vf} \equiv v_o / v_s$, and the input resistance R_{in} as shown in **Fig. 3**. **(10)**

Question 4 [20 marks]

A feedback amplifier using an op-amp is shown in **Fig. 4**.

The following op-amp data is known:

Open-loop voltage gain: $A_{OL} = 2.10^4$;
Differential input resistance: $R_{id} = 30\ k\Omega$;
Output resistance: $r_o = 150\ \Omega$

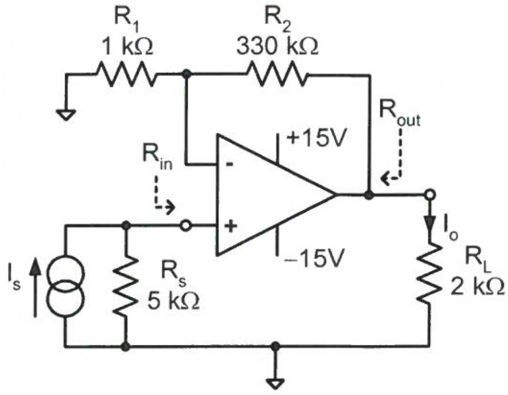

Figure 4

A. Identify the feedback topology of this amplifier, briefly explaining **how** you made this identification, and hence state which transfer gain ("A_f") is stabilized by this feedback. **(4)**

B. Draw an ac equivalent circuit of the "A" network without feedback but including the loading effects of the feedback network, clearly explaining **how** you determined the relevant loading effects. **(4)**

C. For this amplifier *with negative feedback*, determine each of the following:

i. The current gain $A_I = I_o / I_S$; **(8)**
ii. The input resistance R_{in} as seen at the input to the op-amp (as shown). **(2)**
iii. The output resistance R_{out} as seen by the load resistance R_L (as shown). **(2)**

Question 5 [20 marks]

5.1 For the circuit in **Fig. 5.1**, find the loop gain in s-domain and jω-domain and R_2 / R_1 for the oscillation. **(10)**

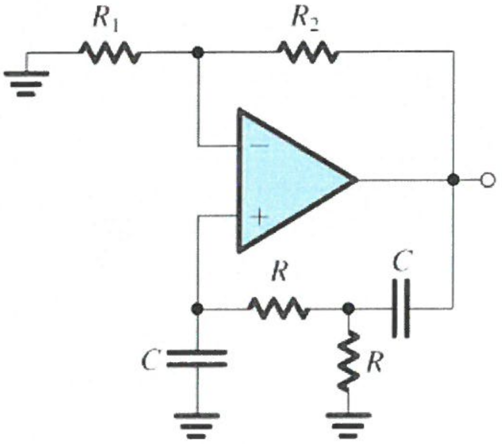

Figure 5.1

5.2 The BJTs in the Darlington follower of **Fig. 5.2** have $\beta = 100$. If the follower is fed with a source having a 100 kΩ resistance and is loaded with 1 kΩ, find the input resistance and the output resistance (excluding the load). **(2+3)**

Also find the overall voltage gain, both open-circuited and with load. **(2+3)**

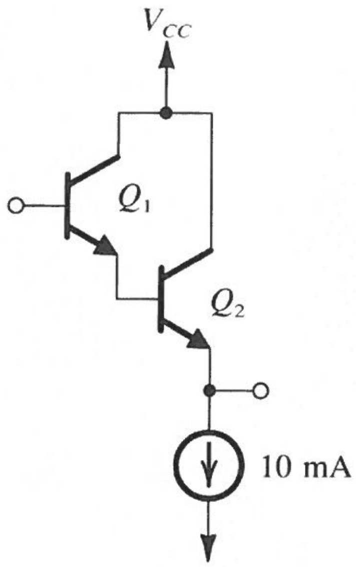

Figure 5.2

END OF QUESTIONS